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SHORT COMMUNICATION

A NOTE ON SAND RIPPLES DEVELOPING IN SANDSTONE ROCK SEEPAGES OF THE WEALD, UK

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ABSTRACT

Ephemeral sand ripples are described from steep rock surfaces in the UK. They are unconsolidated or stabilized by algae and bryophytes. The sand is transported by flowing water to produce a semi-regular pattern of sinuous ripples averaging 6–8 mm apart and with a relief not exceeding 4 mm. The ripples may be initiated by the formation of a self-perpetuating capillary wave template. Sand grains accumulate on the template to form the fully developed ripples. Ultimately, gravitational forces or flooding lead to their destruction. Travertine rimstones may be initiated in the same manner. Copyright © 1999 John Wiley & Sons, Ltd.

KEY WORDS: sand; ripple; algae; bryophytes; seepage; travertine

INTRODUCTION

This study reports on ephemeral sand ripples developing upon steep sandstone rock surfaces in the south of England. They are widespread on the dozens of small outcrops in this region and do not appear to have been previously described. They are deposited without cementation and none of the hypotheses advanced for other wave-like patterns on rock surfaces fully explain them.

STUDY AREA

Two of the many small outcrops of the Ardingly Sandstone (Lower Cretaceous, Tunbridge Wells Sand) occurring in the High Weald of Kent were investigated. These were Rusthall Rocks (NGR 51/568396, alt. 110 m) and Tunbridge Wells Rocks (NGR 51/577393, alt 110 m). The latter have been used for weathering rate studies and are described more fully in Pentecost (1991).

DESCRIPTION

The structures occur on steep, more or less vertical faces of the rocks in areas where rainwater temporarily trickles from local collection points on the irregular and approximately horizontal bedding planes. These are free of vegetation and provide much loose sand through natural weathering, sometimes aided by visitors walking on the rocks. Aspects of the rock faces vary and do not appear to be significant, but the structures were only seen on vertical or slightly overhanging rock. The areas covered were small, ranging from 10–50 cm in width and extending vertically for up to 2 m.

The structures consist of sinuous accumulations of sand forming a wave-like pattern on the bare sandstone. The sand is loose and unconsolidated near the rounded apices of the ripple but was often matted with

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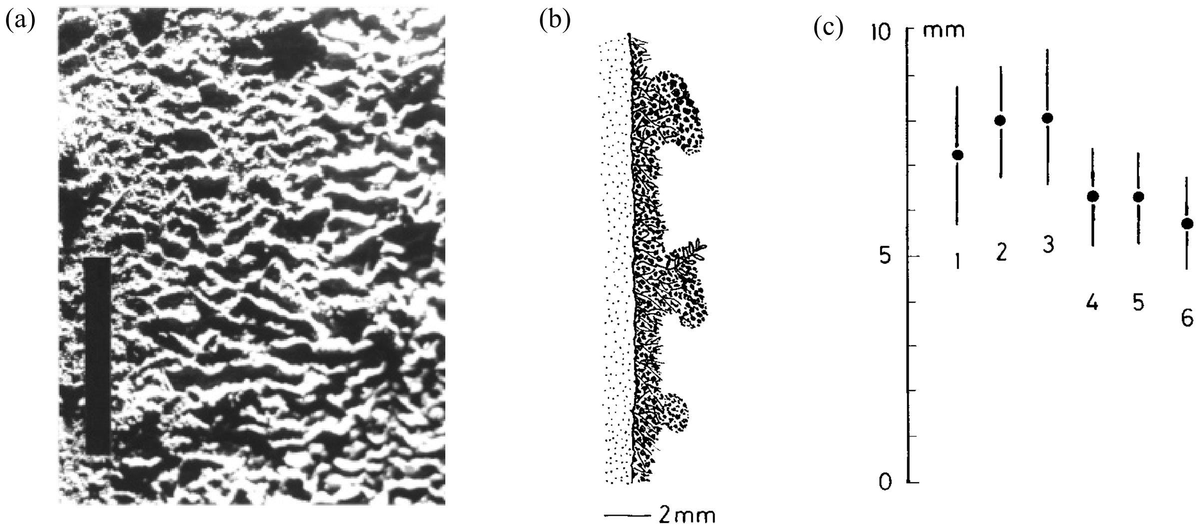

Figure 1. (a) Low-angle flash photograph of sand gours at site 4, Rusthall. Bar 5 cm.(b) Diagram of a section through the cusps showing their form and partial consolidation below by algae and bryophytes. The rounded apices of the cusps consisted of loose, very friable sand without obvious means of support.(c) Means (with 95 per cent confidence limits) of the vertical cusp-to-cusp distance for six transects

bryophytes and algae below. The ripples run approximately horizontally along the surface and frequently merge with each other to form a semi-regular wave-like pattern (Figure 1 a). The average relief of the ripples is about 2 mm and did not exceed 4 mm. In section they are broadly club-shaped and asymmetrical, overhanging more on the lower side (Figure 1 b). They were composed of approximately equidimensional quartz sand grains. A sand sample from Rusthall gave a mean diameter of 0·22 mm with standard deviation 0·06 mm ($n = 50$).

Measurements were made along vertical transects of six series of these structures to determine the magnitude and spatial pattern of the inter-ripple distance (Table I). The mean inter-ripple distance ranged from 5·6 to 8·0 mm (Figure 1 c). The variance ranged from 1·71 to 14·5 mm and a Kruskall–Wallis test indicated no significant difference between the population medians ($H = 8{\cdot}60$, $p = 0{\cdot}126$). A variance-to-mean ratio test (Diggle, 1983) suggested that five of the six sequences were randomly distributed whilst one had a regular distribution (Table I).

Along five of the six transects, the stabilizing mat consisted of the moss *Dicranella heteromalla* (Hedw.) Schimp., and at all sites the sand grains were bound to some extent by the moss protonema and the coccoid algae *Chlorococcum, Gloeocapsa* and *Mesotaenium*. However, at site 2, moss was absent and algae were scarce.

Table I. Site analyses

No.	Site	n	Mean* (mm)	s.d.* (mm)	χ^2*	Distribution*	Aspect (deg.)	Slope (deg.)	Vegetation†
1	TW	19	7·21	7·26	18·1	Random	340	90	D
2	TW	11	7·9	14·5	18·3	Random	130	88	A
3	TW	12	8·0	12·2	16·8	Random	100	86	D + A
4	RH	19	6·25	4·95	14·2	Random	300	−5	D + A
5	RH	23	6·13	5·84	20·9	Random	”	”	D + A
6	RH	25	5·6	1·71	7·3	Regular	”	”	D + A

* The statistics refer to the cusp-to-cusp distances in vertical transects
† D = *Dicranella* (a moss); A = coccoid algae
Site-numbers 4–6 refer to a larger area of structures where three separate transects were measured
n refers to the number of cusps per transect

DISCUSSION

It is clear that the ripples are formed from flowing water during wet weather. When the ripples were observed on a rainy day, a thin water film carrying sand grains was seen to flow along the upper surface of the ripples, descending at their edges to the ripple beneath. In some places, the water passed across a ripple in a shallow water-cut groove which did not completely divide the ripple. The resulting water flow was complex, often switching back and forth down the rock face in a zig-zag descent. Sand grains entrained in the flow followed the same pattern, with some presumably deposited on the upper ripple surface. Some water also flowed through the body of the ripples since sand which was little colonized by algae was porous, but the flow was difficult to observe. Water was not observed to flow over the lips of the ripples though this may have occurred during heavy rain.

The process of formation is unknown, but several facts can be established. First, it was clear that the ripples began as a network of fine sand lines on the rock surface with a relief of less than 1 mm, since these were seen in recently eroded areas. Second, the ripples did not appear to be migratory since they became colonized by cryptogams which implied a degree of stability. The ripples are clearly the result of water flow carrying sand grains and they only form on steep surfaces. Their lifetime, however, must be short due to their friability and it is unlikely that they survived for more than a few years. Plants, although providing some stability to the ripples, are probably unnecessary for their formation since similar ripples are a common feature of motor vehicle wheel arches. Here they presumably develop as a result of tyre spray but are difficult to observe on account of their inaccessibility.

Any explanation of these structures at this stage must be speculative though parallels may be sought with other wave-like phenomena developing at solid/fluid interfaces. Two are worthy of mention, namely the ripple marks formed on sand sediments beneath water and the terracettes developing on steep travertine in caves and hot springs. Ripple marks share the same substratum type but here the analogy must end because these are formed by the to-and-fro movement of a water mass induced by gravity waves. There is no unidirectional water movement along the 'valleys' of such ripples and the ripples are cusped. The terracettes or 'gours' seen in some travertine deposits appear strikingly similar to the sand ripples described above. Their inter-ripple distance is of the same order and they also possess a sinuous form. Water trickles over the surface in a complex manner but the analogy is not complete since the deposition process differs. The travertine is chemically precipitated mainly on the cusps, probably due to the sudden change in flow velocity over them (Varnedoe, 1965).

The initiation of the cusps and their spacing has yet to be explained though they are likely to depend upon physical rather than chemical or biological processes. For example, a standing capillary wave could be generated by small irregularities on the rock surface. These could result in regions favourable to deposition, which once produced would become self-perpetuating (cf. Shaw, 1979, and references therein). The crest-to-crest distance may thus be a function of water surface tension, water density and the rate of flow, which would need to be reasonably constant. Crest-to-crest distances would then be expected to be regularly distributed, but with their sinuosity often leading to a random pattern. Thus it is likely that the initiation stage is responsible for the overall form and spacing of both travertine rimstones and sand ripples, followed by an accretion stage of diverging patterns dependent upon the resulting physico-chemical processes.

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